Regional Routing Model:
Progress To Date

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OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

RRM MODELING OBJECTIVES

Given a set of broad regional and commodity specific demands and supplies and a multimodal transportation network, the RRM is meant to:

1. develop a base year set of origin, destination, commodity and mode specific (O-D-C-M) annual waterway-relevant commodity flows;

2. carry out a congestion sensitive and commodity specific assignment of these traffic flows to the appropriate sections of the nation's multimodal transportation network;

3. derive a set of O-D-C-M specific costs of movement associated with these modally assigned flows; and

4. estimate the effects of significant changes in commodity production, consumption and network conditions (network capacity, carrier rates, shipper costs) on within-region patterns of commodity flows across modes and routes.*

* and eventually also between markets

Regional Routing Model Review:

Presentation Outline

A) NETS Context

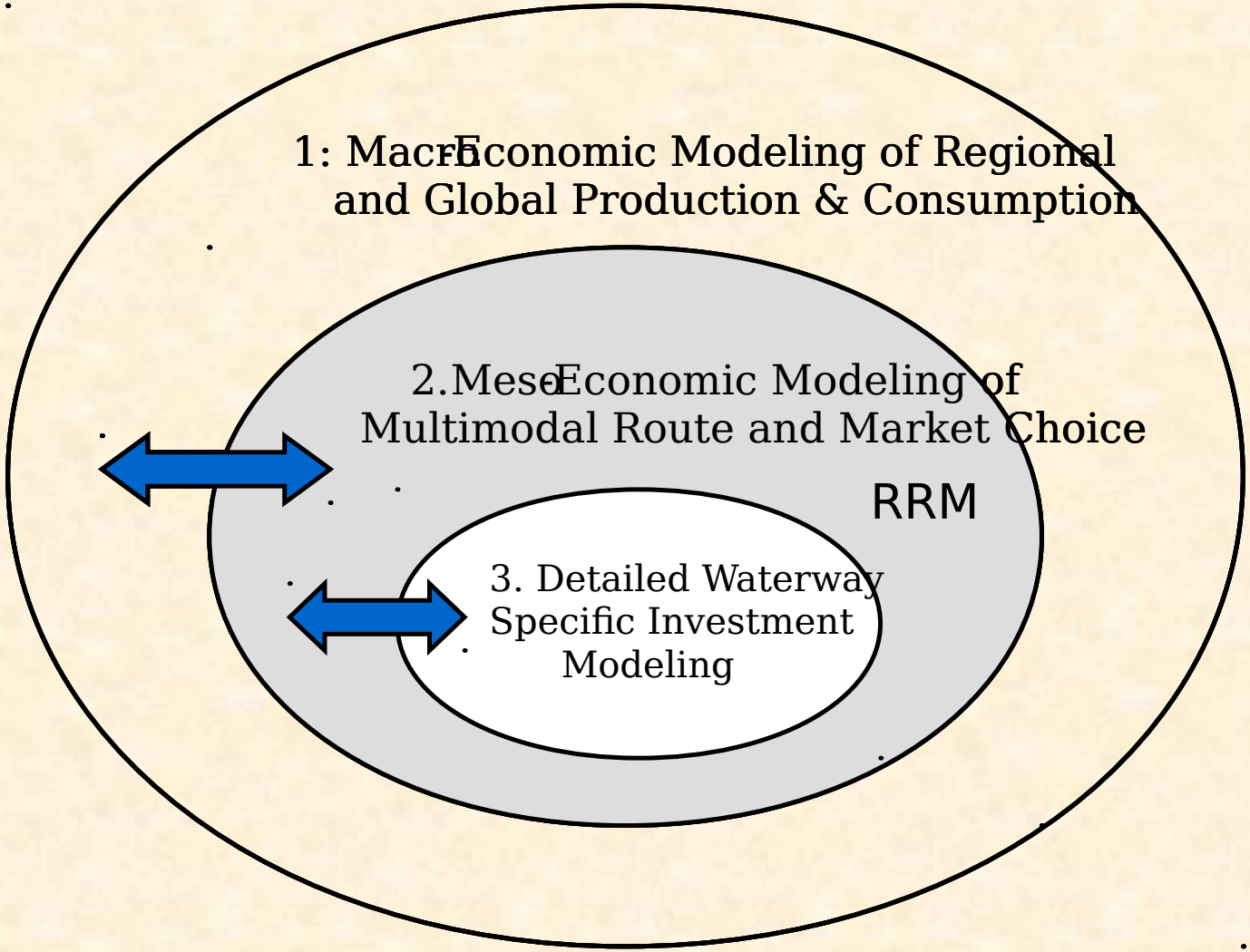
B) Database & Model Development

- RRM Overview
- Truck Movements Sub-model
- Truck-Rail/Truck-Water Mode Split Sub-Mod
- National/Regional Network Assignment Mod

C) RRM Scenario Analysis

D) Data and Modeling Issues

NETS CONTEXT: NESTED THREE-TIER SPATIAL-ECONOMIC MODELING FRAMEWORK


1: Macro-Economic Modeling of Regional and Global Production & Consumption
2. Meso-Economic Modeling of Multimodal Route and Market Choice
RRM
3. Detailed Waterway Specific Investment Modeling

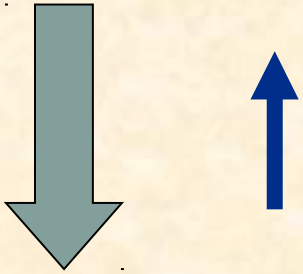
= feedback between levels

THREE-TIER SPATIAL-ECONOMIC MODELING FRAMEWORK : I/O CONNECTIONS

Broad Regional Commodity Flows (Scenarios/Forecasts)

Revised Inter-Regional Transport Costs

Within Regional Commodity Flows and Costs Assigned to Origin-Destination Pairs and Modal Networks



Rates & Revised Transit Times and Flows

Detailed Origin-Destination-Commodity-Mode Costs and Commodity Flows Assigned to Networks and Converted to Vessels/Vehicles

NETS CONTEXT: LEVEL OF MODEL RESOLUTION

1) Level of Temporal Detail = Annual Flows
2) Level of Commodity Detail

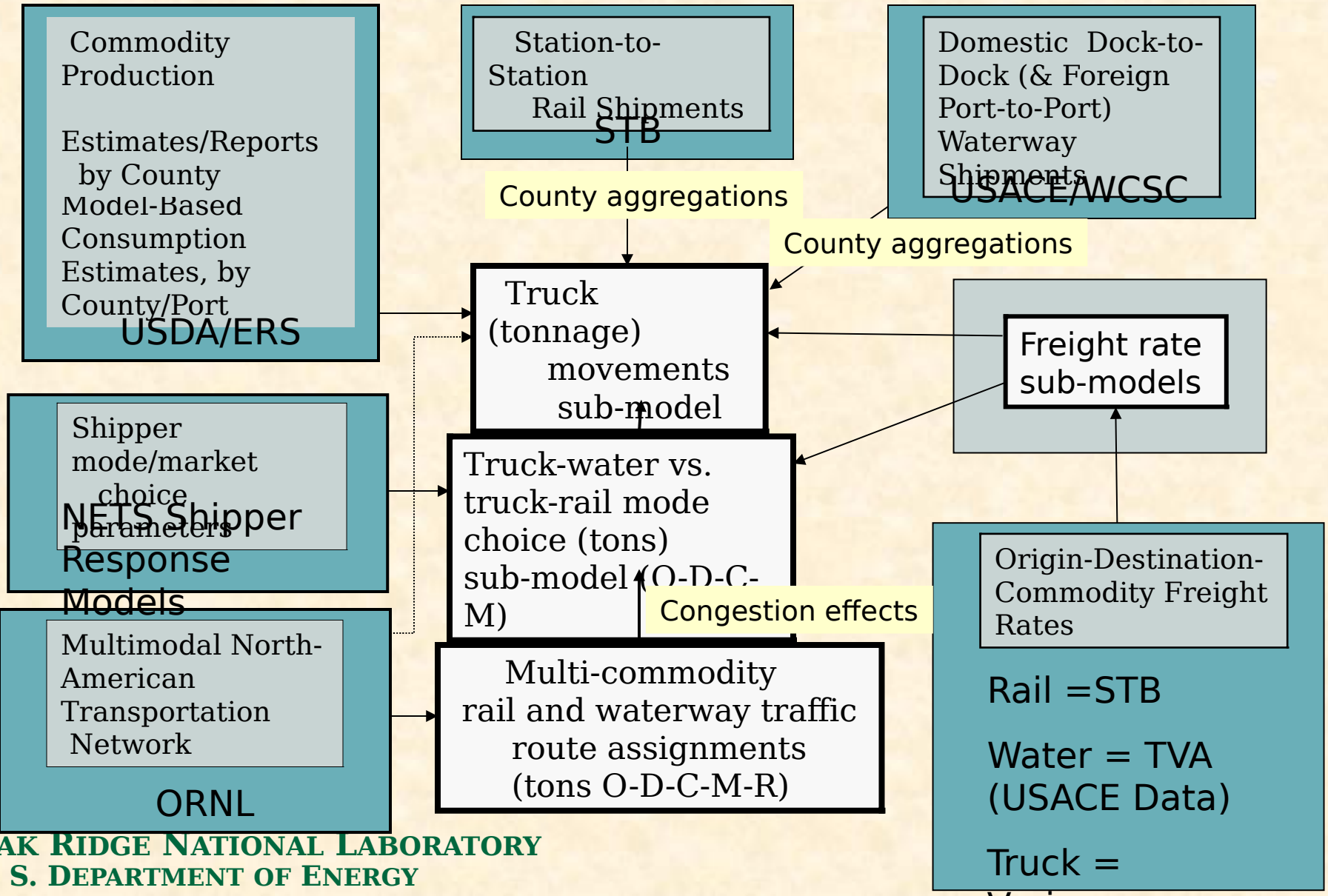
14 USACE Commodity Classe
used for national routing mo

1 Coal (and coal coke)
2 Petroleum and petroleum products
3 Chemicals and related products
4 Crude materials, inedible except fuels
5 Primary manufactured goods
6 Food and farm products - except grains
7 All manufactured equipment, machinery and products
8 Waste and scrap nec
9 Unknown and not elsewhere classified
10 Units - vehicles and passengers (WCSC class 00)
11 Other grains
12 Wheat
13 Corn
14 Soybeans

3) Level of Spatial Detail

Waterway Dock-to-Dock and Rail Station-to-Station Flows
Aggregated to County-to-County Flows

RRM OVERVIEW: SUB-MODELS AND DATA SOURCES



What is the Output of the Data Fusion Effort prior to Running the Models?

All 14 Commodities

By Rail, Water – O/D Flows

By Cost (Rate)

By County level Production/Consumption

Shipper Mode Choice Elasticity (approximation)

Mutlimodal Network

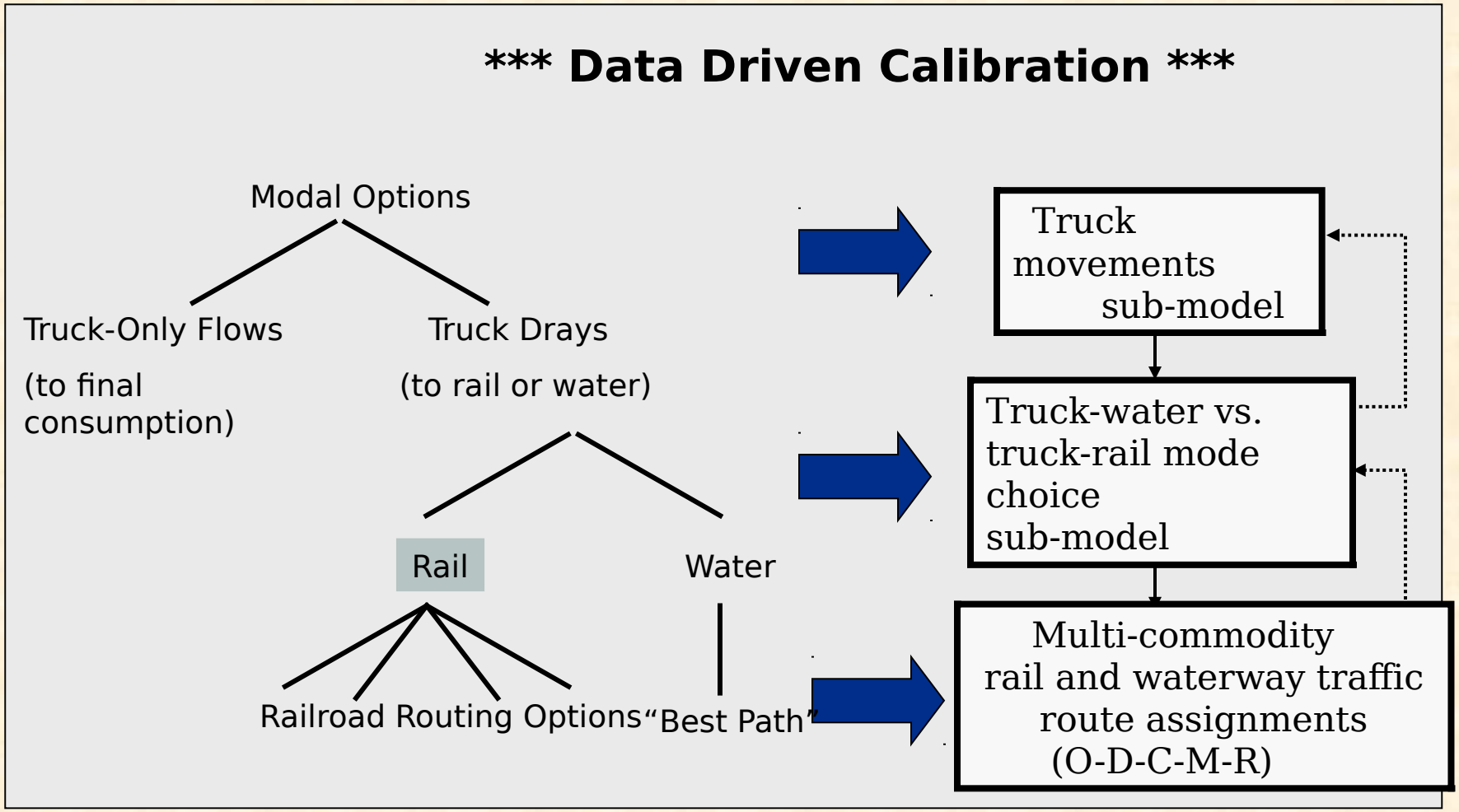
Information on Truck Trip Distances

Why did we integrate the USDA /STB /WCS/TVA/ ORNL/Other data?

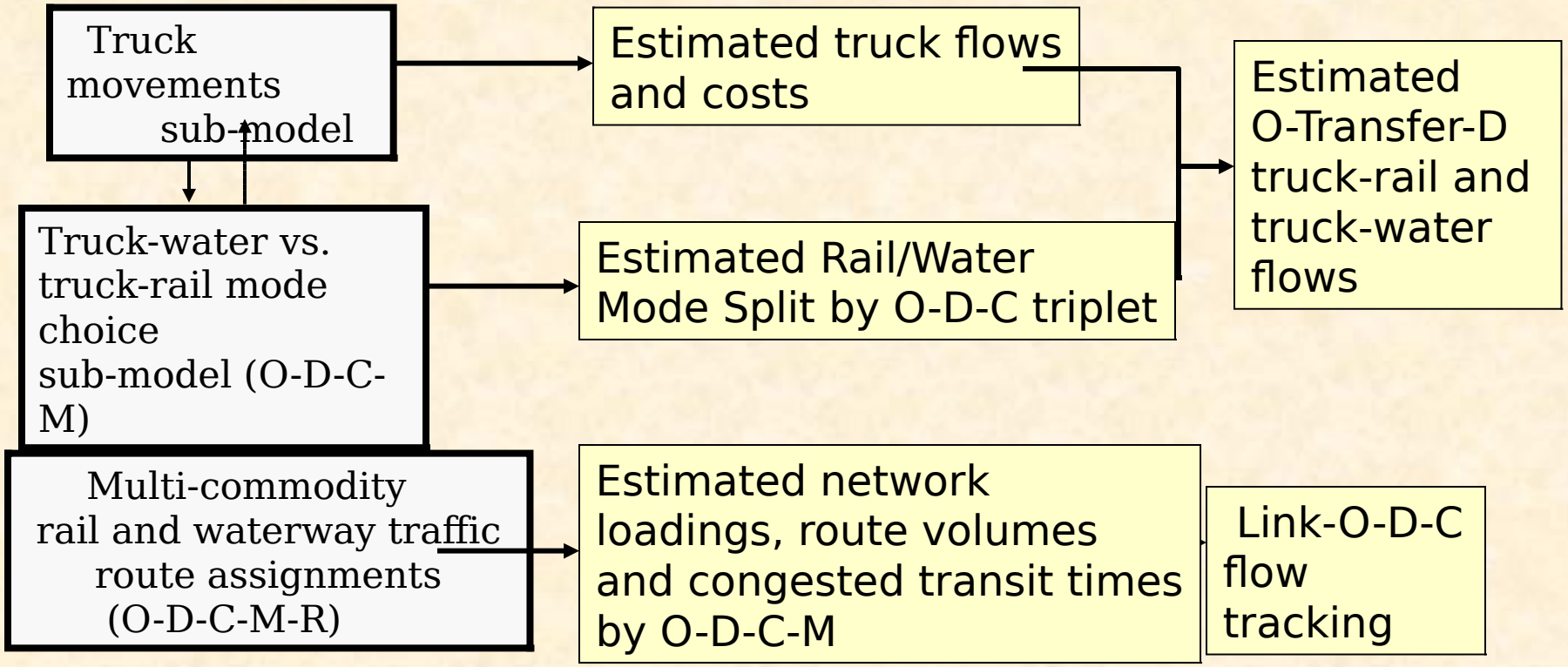
Issue: To estimate true origin-to-destination commodity movements (not just dock-to-dock or station-to-station flows)

i.e. truck dray costs impact significantly mode choice

RRM OVERVIEW: MODE/ROUTE CHOICE STRUCTURE



RRM OVERVIEW: PRINCIPAL OUTPUTS


Truck movements sub-model
Estimated truck flows and costs
Estimated O-Transfer-D truck-rail and truck-water flows
Truck-water vs. truck-rail mode choice sub-model (O-D-C-M)
Estimated Rail/Water Mode Split by O-D-C triplet
Multi-commodity rail and waterway traffic route assignments (O-D-C-M-R)
Estimated network loadings, route volumes and congested transit times by O-D-C-M
Link-O-D-C flow tracking

TRUCK MOVEMENTS SUB-MODEL

Key issue: Distance to water is a key determinant of mode split. Many truck drays cross county boundaries. However, we have found limited statistically useful data on the distances and costs (rates) associated with such drays. So we need to estimate which counties s specific railhead or riverside docks?

Truck shipments are either:

A) “Truck-Only” to a consumption point (processing plant, etc.); or
B) ”Truck-Intermodal” (Drays) to an inter-modal transfer point.

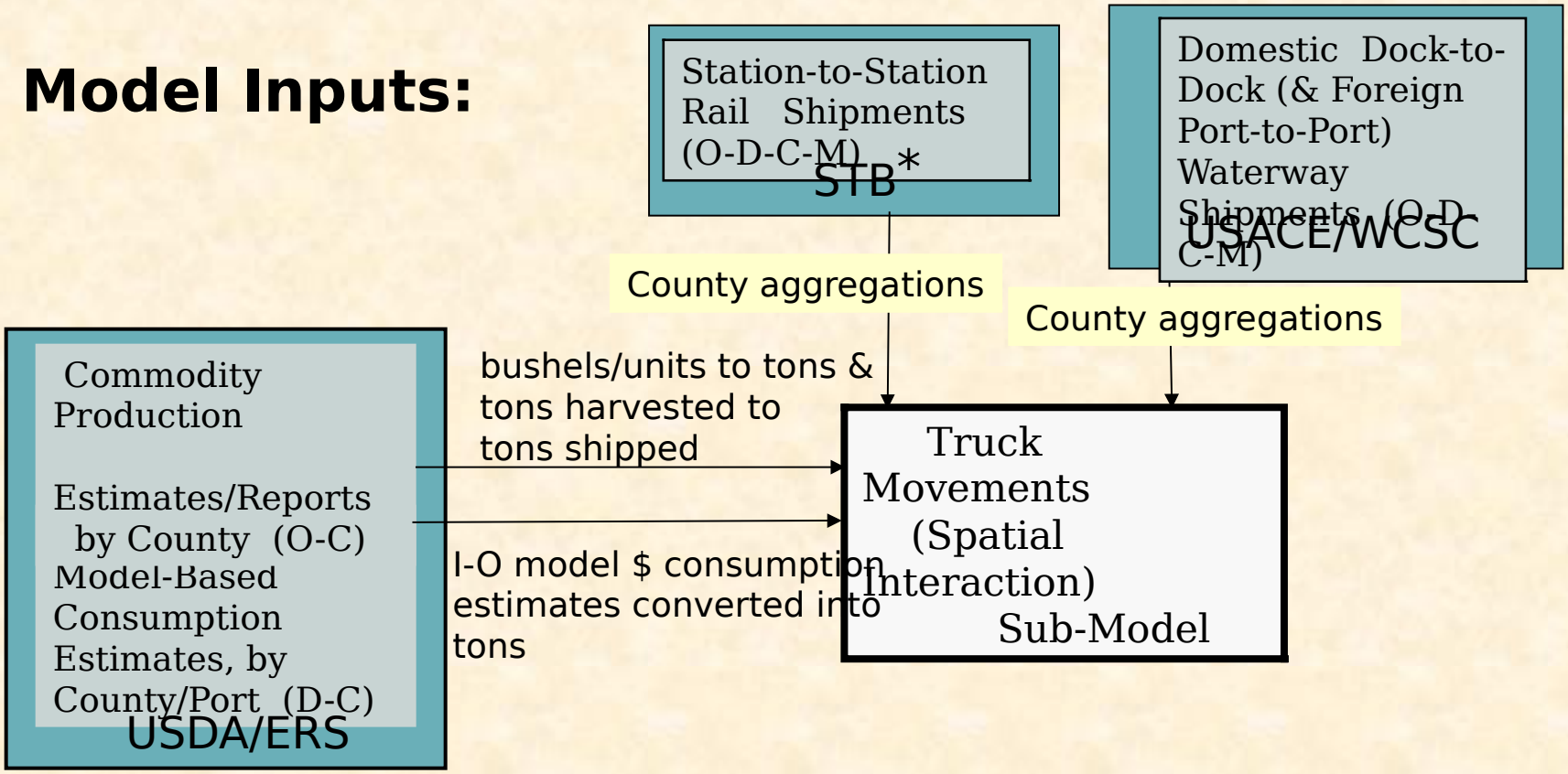
In the general case we have poor data on the truck volumes associated with A but reasonably good data on the volumes associated with B.

What we do have is:

USDA county production and consumption estimates
STB and WCSC rail and waterway loading data

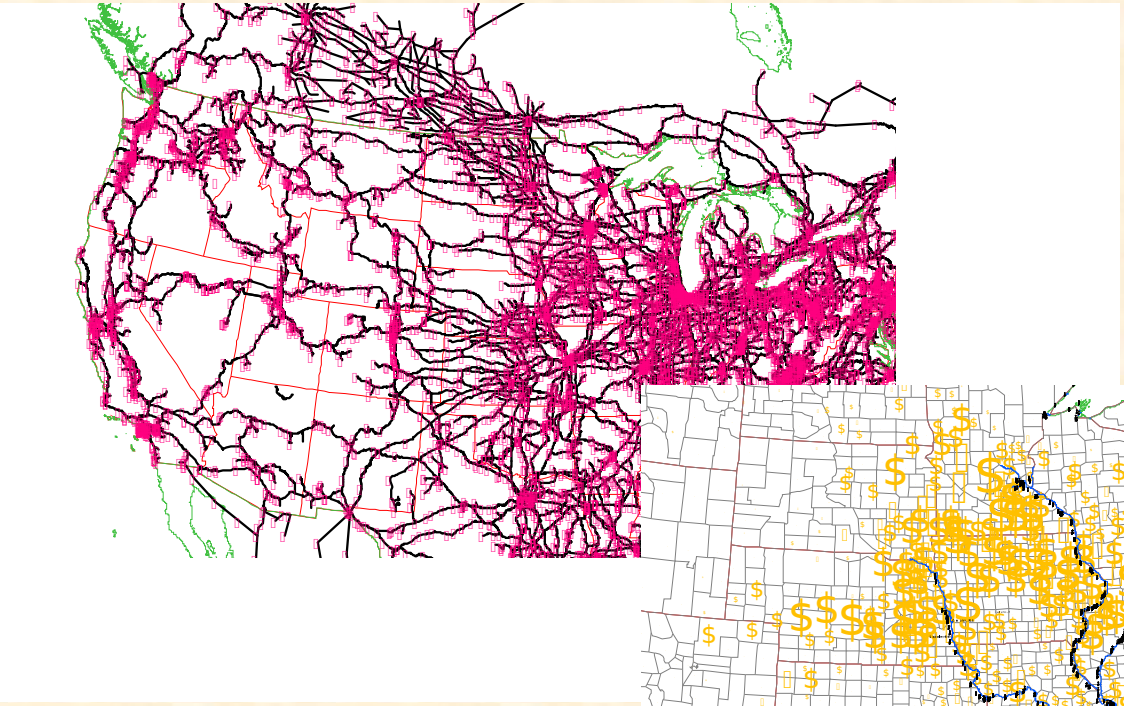
TRUCK MOVEMENTS SUB-MODEL

Model Inputs:

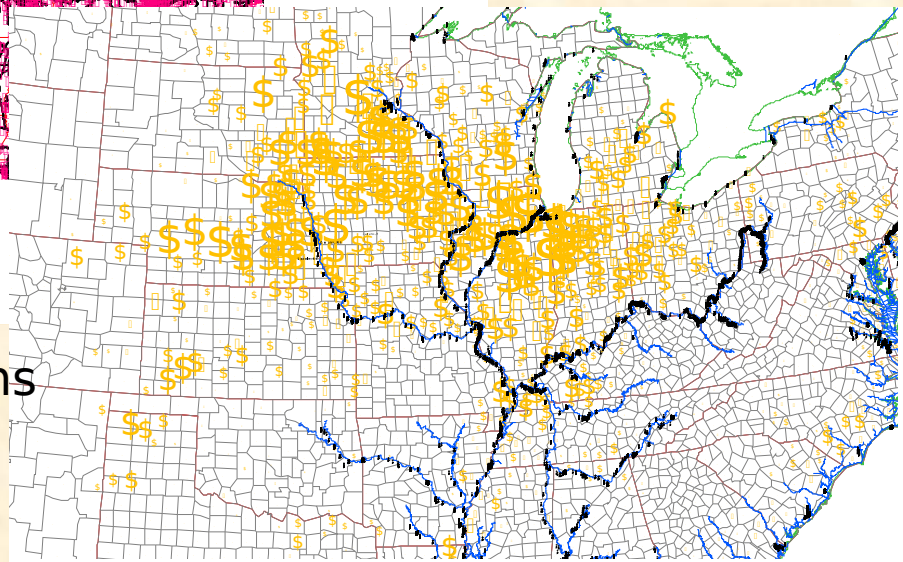

Station-to-Station Rail Shipments (O-D-C-M)
STB*
Domestic Dock-to-Dock (& Foreign Port-to-Port) Waterway Shipments (O-D-C-M)
USACE/WCSC
County aggregations
County aggregations
Commodity Production
Estimates/Reports by County (O-C)
Model-Based Consumption Estimates, by County/Port (D-C)
USDA/ERS
bushels/units to tons & tons harvested to tons shipped
I-O model $ consumption estimates converted into tons
Truck Movements (Spatial Interaction) Sub-Model

* micro-data sample: restricted use

County-to-County Aggregations of Rail and Waterway Loading Stations/Do

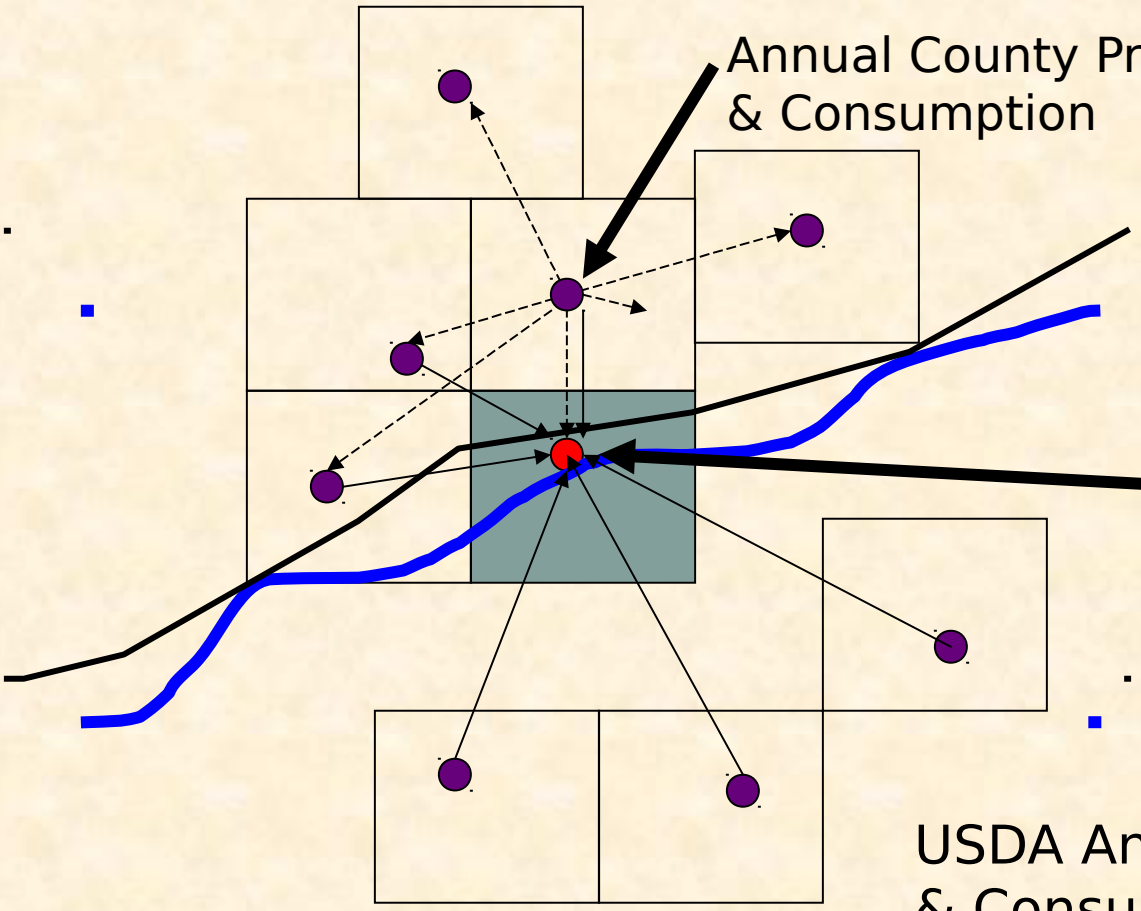


Rail SPLC code-based stations



Waterway Docks Data

TRUCK MOVEMENTS SUB-MODEL



USDA Annual Production & Consumption

STB & WCSC Intermodal Loadings

TRUCK MOVEMENTS SUB-MODEL

A quasi-constrained spatial interaction model is used to allocate truck shipments from the county of production, i, to county of destination, k as:*

$$T(i,k) = A(i)^{1-\alpha} \; G(i) * B(k)^{1-\gamma} * D(k) * \exp(-\beta * c(i,k))$$

for:

T(i,k) = Tons of freight moved by truck from county I to county k

G(i) = volume of grain produced in county i (minus on-farm use) (USDA)

D(k) = demand in county k (= the sum of consumption of grain in k's industries plus the volume of grain loaded on rail or barge in county k) (USDA)

c(i,k) = the cost of trucking a ton from i to k, and where α, β, and γ are model parameters to be estimated (Truck rate model)

β = model parameter calibrated to reproduce the average distance traveled (CFS)

and α and γ are parameters estimated to allow the resulting T(i,k) estimates to sum more or less closely to the input P(i) and D(k) totals, by way two sets of trip end balancing factors A(i) and B(k):

*ee, for example, de Vries, J.J., Nijkamp, P. and Rietvled, P. (2000) Alonso's General Theory of Movement bergen Institute Discussion Paper T1 2000-062/3. Erasmus University, Amsterdam, Netherlands.

TRUCK MOVEMENTS SUB-MODEL

i.e.,

$$A(i) = [\ \sum_k\ B(k)^{1-\gamma}\ * D(k) * \exp(-\beta * c(i,k))^{-1}\ ]$$

$$B(k) = [\ \sum_i A(i)^{1-\alpha} * G(i) * \exp(-\beta * c(i,k))^{-1}\ ]$$

Linking these flows to the rail and waterway line haul tonnages gives the estimated tons shipped from production county i via a rail or barge loading in county k to a rail or barge destination in county j as:

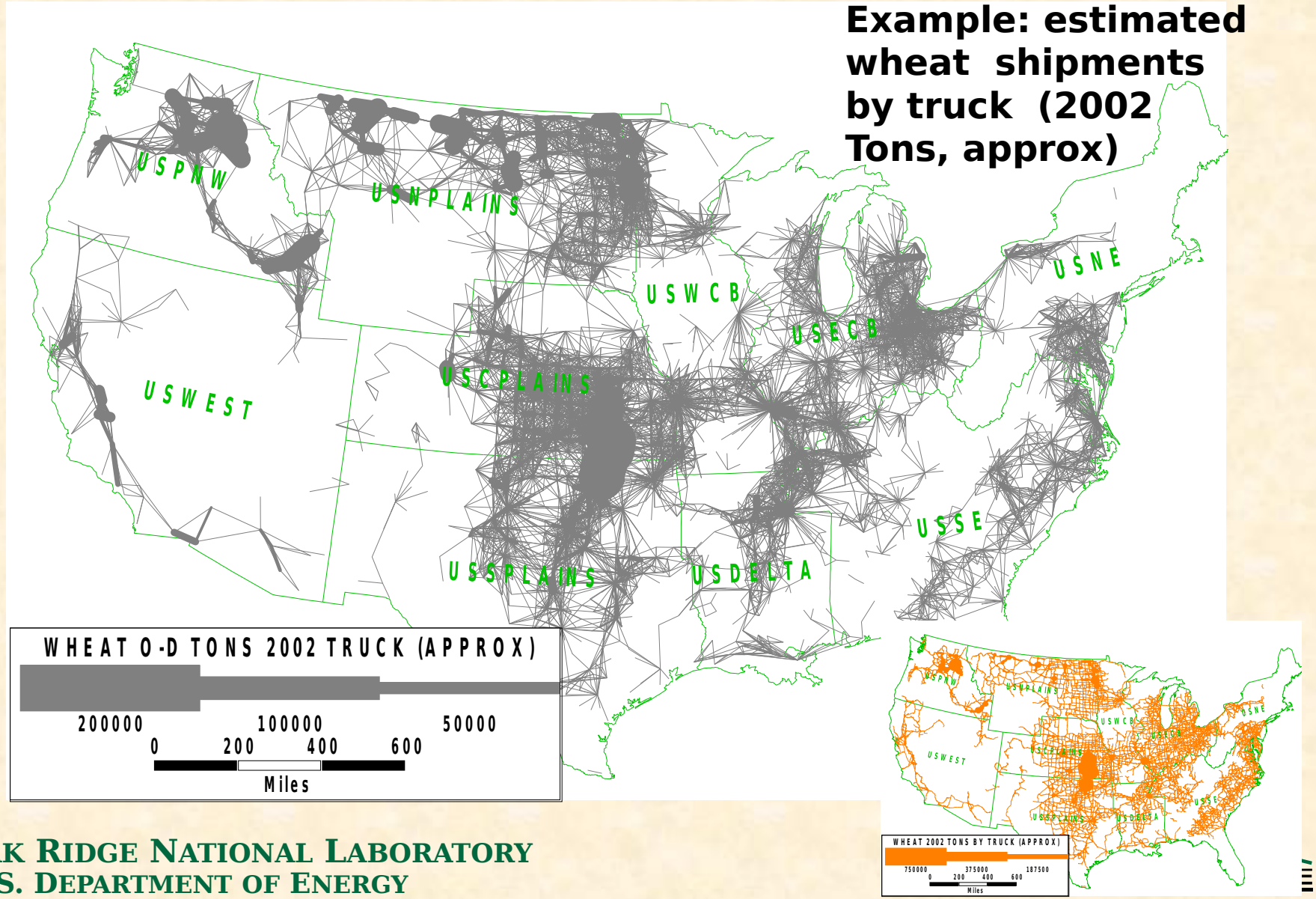
$$T(i,k,j) = T(k,j)*P(i/k)$$

for T(k,j) = tons shipped from rail and/or water loading county j to destination county k and P(i/k) = the probability of selecting county i as a source for loading freight arriving by truck at county k.

The result is a compromise between USDA production/consumption figures (converted to tons), and STB and WCSC mode-specific trip loading/unloading totals (also in tons).

TRUCK MOVEMENTS SUB-MODEL

Model Output:



TRUCK-RAIL vs. TRUCK-WATER MODE CHOICE SUB-MODEL

Key issues:

A> How do we incorporate shipper preferences/concerns/behavio
in the modeling?

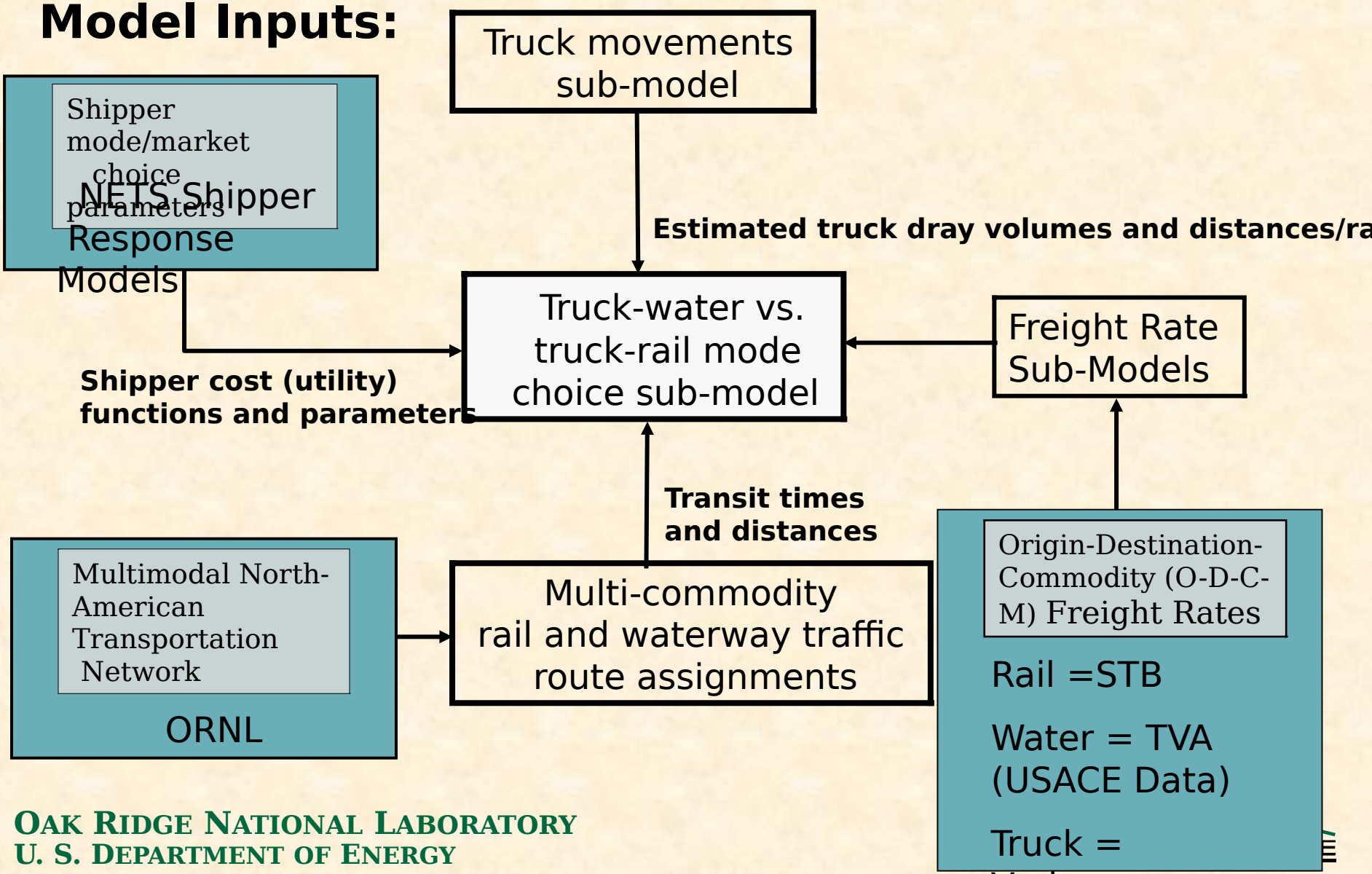
- Incorporating NETS shipper response study findings

B> How do we validate the modeling results?

- How good are the resulting transit time and rate respons
"elasticities"?
- What sort of ranges should these parameters take?
(Limited, but some, literature to draw on).

TRUCK-RAIL vs. TRUCK-WATER MODE CHOICE SUB-MODEL

Model Inputs:


Truck movements sub-model
Shipper mode/market choice parameters
NETS Shipper Response Models
Estimated truck dray volumes and distances/ra
Truck-water vs. truck-rail mode choice sub-model
Freight Rate Sub-Models
Shipper cost (utility) functions and parameters
Transit times and distances
Multimodal North-American Transportation Network
ORNL
Multi-commodity rail and waterway traffic route assignments
Origin-Destination-Commodity (O-D-C-M) Freight Rates
Rail =STB
Water = TVA (USACE Data)
Truck = Various

TRUCK-RAIL vs. TRUCK-WATER MODE CHOICE MODEL

INCORPORATING NETS SHIPPER CHOICE MODELING:

$$P_{ij}^{mg} = P_{ij}^{g} * [\exp(-\lambda_0^m + \lambda_1^m (c_{ij}^{mg}) / \sum_m \exp(-\lambda_0^m + \lambda_1^m (c\ ij^{mg}$$

$$))]$$

where m=mode, g = commodity, i=origin, j=destination, and

λ_0^m and λ_1^m = parameters that fit the generalized cost f
to county annual mode split totals

and where

$$c_{ij}^{mg} = \alpha 0 + \alpha 1\ r_{ij}^{mg} + \alpha 2\ t_{ij}^{mg} \ldots\ldots + \alpha 3\ v_{ij}^{mg}$$

= generalized cost of shipping, where the α's are pre-es
model parameters* and r = **freight rate**, t = **transit ti**
v = variability in travel time

ee, for example, Train, K. and Wilson, W. W. (2005) Transportation demand for grain shipments: revealed and stated preference approach. Transportation Research Board Meetings CD-Rom, January 20

TRUCK-RAIL vs. TRUCK-WATER MODE CHOICE SUB-MODEL

ADDING TRUCK DRAY COSTS

Travel times and costs (rates) are a combination of truck drayage and rail or waterway line-haul times and costs, i.e.

t_{ij}^{m} = t (truck, i,k) + t (rail or water, k,j) + t (k transfer time)

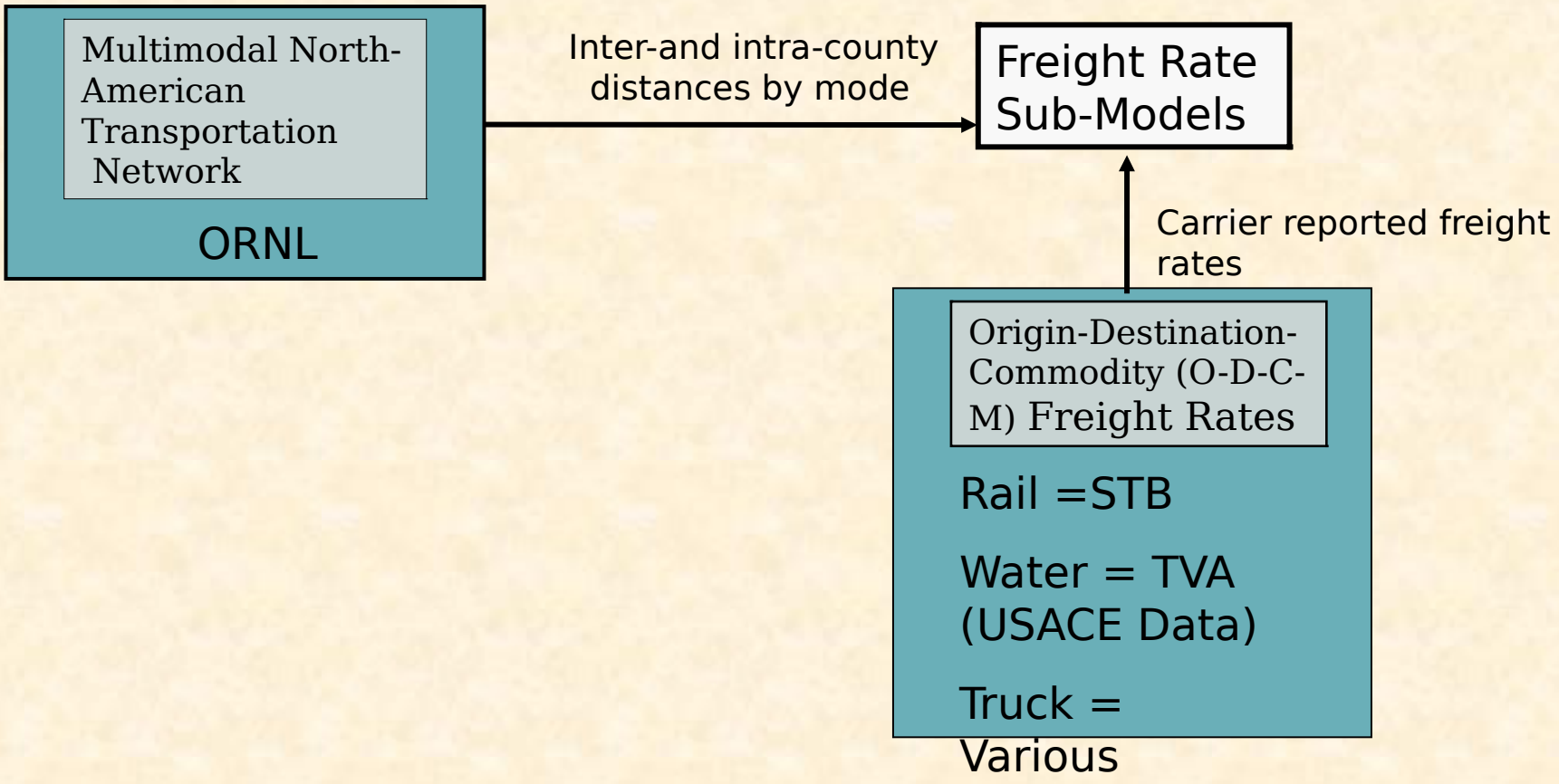
and

r_{ij}^{m} = r (truck, i,k) + r (rail or water, k,j)

Note: r(k, transfer) is currently assumed captured in shipper rate

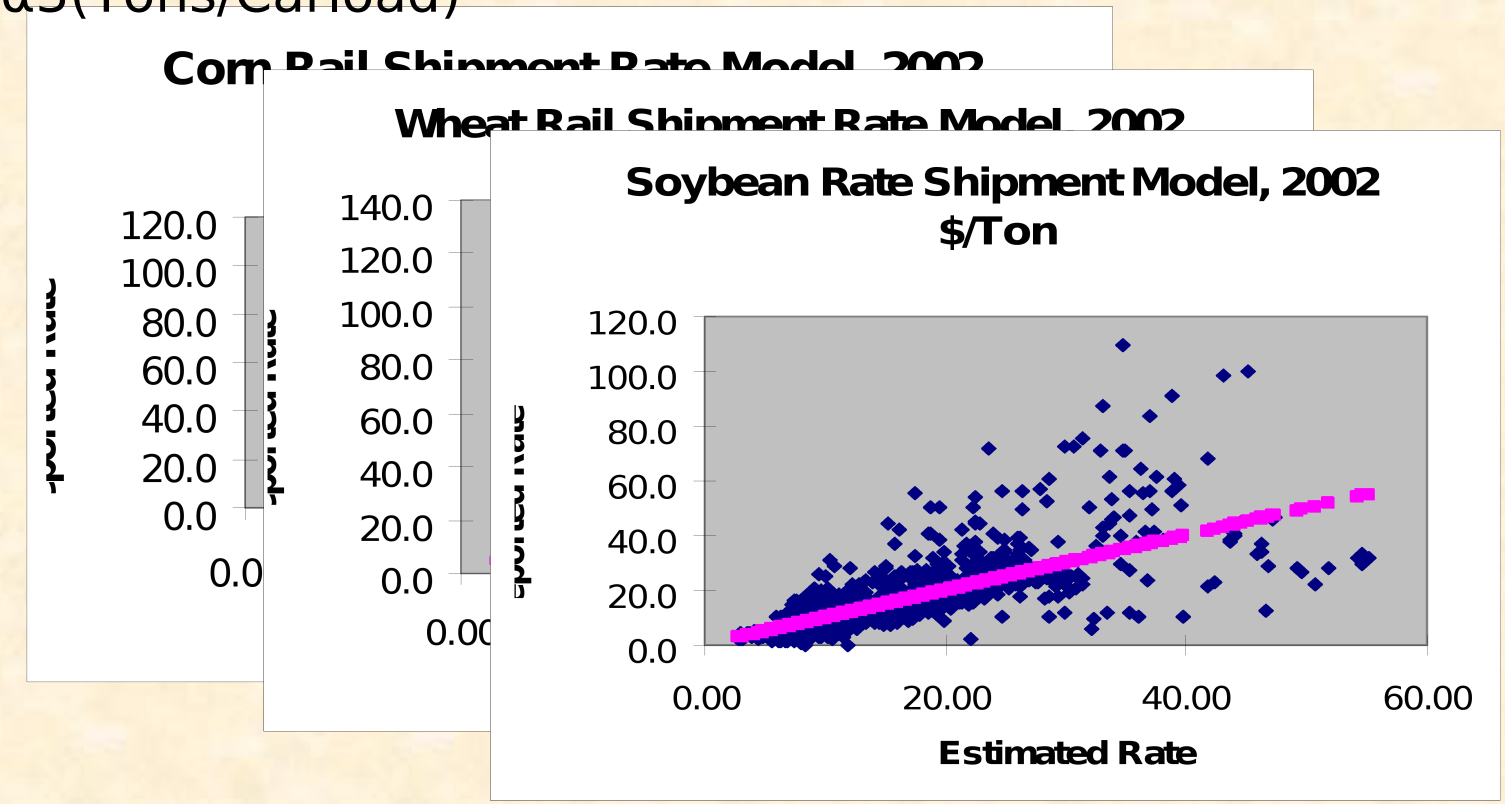
FREIGHT RATE SUB-MODELS

Model Inputs:



FREIGHT RATE SUB-MODELS: A) RAIL

$r(\$/ton) = \alpha 0 + \alpha 1(Miles) - \alpha 2\ (Carloads/Shipment) - \alpha 3(Tons/Carload)$*



* See, for example: 1) Fuller, S., Yo, T-H, Collier, D., Jamieson, J. and Harrison, R. (2001) Texas Grain Transportation Study. University of Texas and Texas A&M University. Report to the 77th Texas Legislature; and 2) Bitzan, J., Vachal, K., Van Wechel, T. and Vinje, D. (200 The Differential Effects of Rail Rate Deregulation: U.S Corn, Wheat and Soybean Markets. Upper Great Plains Transportation Institute, MCP 03-114. North Dakota State University

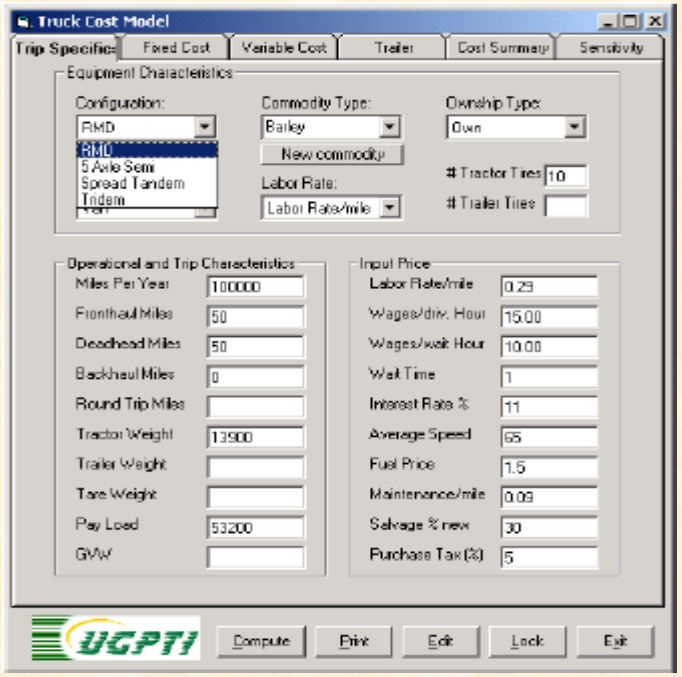
FREIGHT RATE SUB-MODELS: B) TRUCK

TRUCK RATES are based on distance traveled:

e.g.1 Simple distance-based mode: Wilson et al (2005, page 50)*:

truck rate = 4.12 – 0.472 * ln(miles)

Also being experimented with: Berwick and Faroog's (2003) more complex, engineering cost-based "Truck load Analysis Model" **:

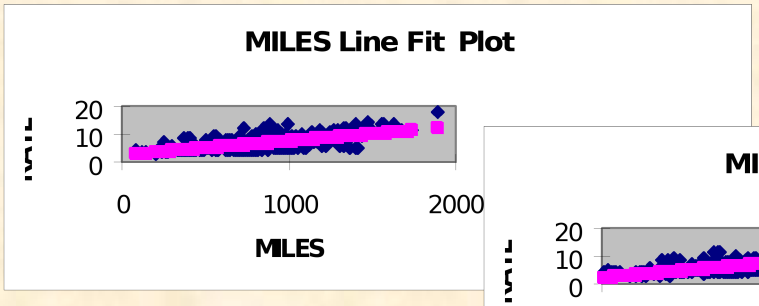


* Wilson, W.W., DeVuyst, E. , Koo, W., Dahl, B. and Taylor, S. (2005) Longer-term forecasting of commodity flows on the Mississippi River: application to grains and world trade. North Dakota State University, Fargo, ND 58105.

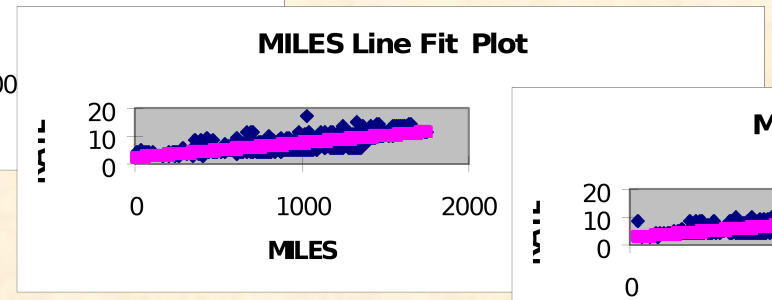
** Berwick, M. and Faroog, M. (2003) Truck Costing Model for Transportation Managers. Upper Great Plains Transportation Institute. North Dakota State University.

FREIGHT RATES SUB-MODEL: C) WATERWAYS

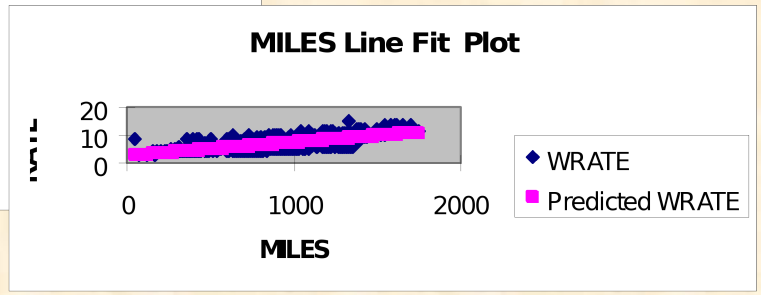
1) Currently using simple distance-based model:



Wheat



Corn



Soybeans

R-squares in range 0.48 to 0.56

2) In the future rates will be supplied by TVA based on exte analysis and modeling of missing rates (C. Dager et al) (- no current rates for Columbia-Snake River System)

NATIONAL/REGIONAL FREIGHT ASSIGNMENT MODEL

Keys issues:

> How do we capture the effects of changes in networks, flows, demands and supplies from other regions on within-region movemen by water?

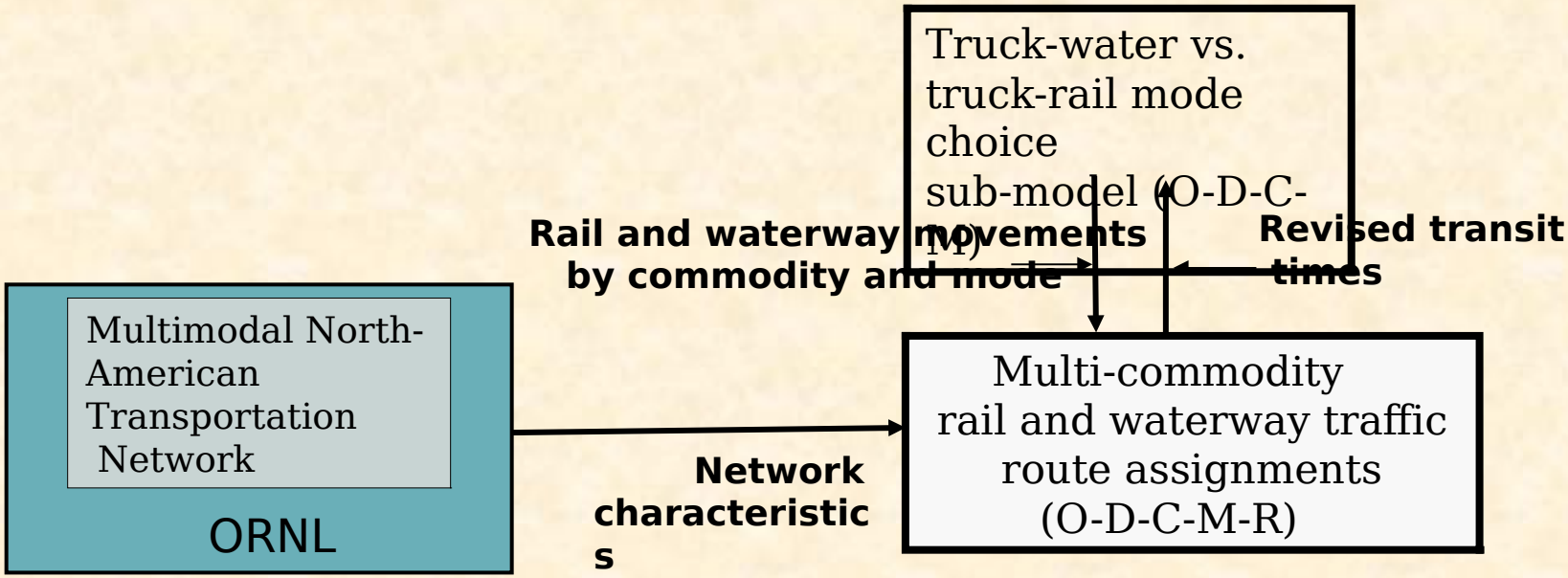
-- must deal with potential changes in long-distance, inter-reg rail flows

> How do we measure rail line and waterway capacities and their effects on rates and transit times?

> How do we capture commodity specific routing decisions by railroa

NATIONAL/REGIONAL FREIGHT ASSIGNMENT MODEL

Model Inputs:


Truck-water vs. truck-rail mode choice sub-model (O-D-C-M)
Rail and waterway movements by commodity and mode
Revised transit times
Multimodal North-American Transportation Network
ORNL
Network characteristics
Multi-commodity rail and waterway traffic route assignments (O-D-C-M-R)

MULTI-COMMODITY RAIL ASSIGNMENT SUB-MODEL

METHOD: A Multi-Path, Congestion-Sensitive (Equilibrium Approximating) Railroad Specific Assignment

APPROACH: Route selection is based on line-haul travel time = F(distance, estimated traffic volume, track class and estimated capacity**,interlining requirements and trackage rights)

** double stacking, CTC signalling

VALIDATION: based on information contained in STB Railcar Waybills and other published sources.

Link Line Haul Transit Time Functions have the general form:

t = t0 * (A * v/c**N + 1)

where v/c is traffic/nominal capacity, and A and N are model parameter base case transit times and subjective mainline classifications have been developed over time to reproduce observed railroad routing decisions.

MULTI-COMMODITY WATERWAY ASSIGNMENT SUB-MODEL

METHOD: Congestion Sensitive Least Cost Single Path Assignment (Currently)

APPROACH: Line-haul travel times are based on:

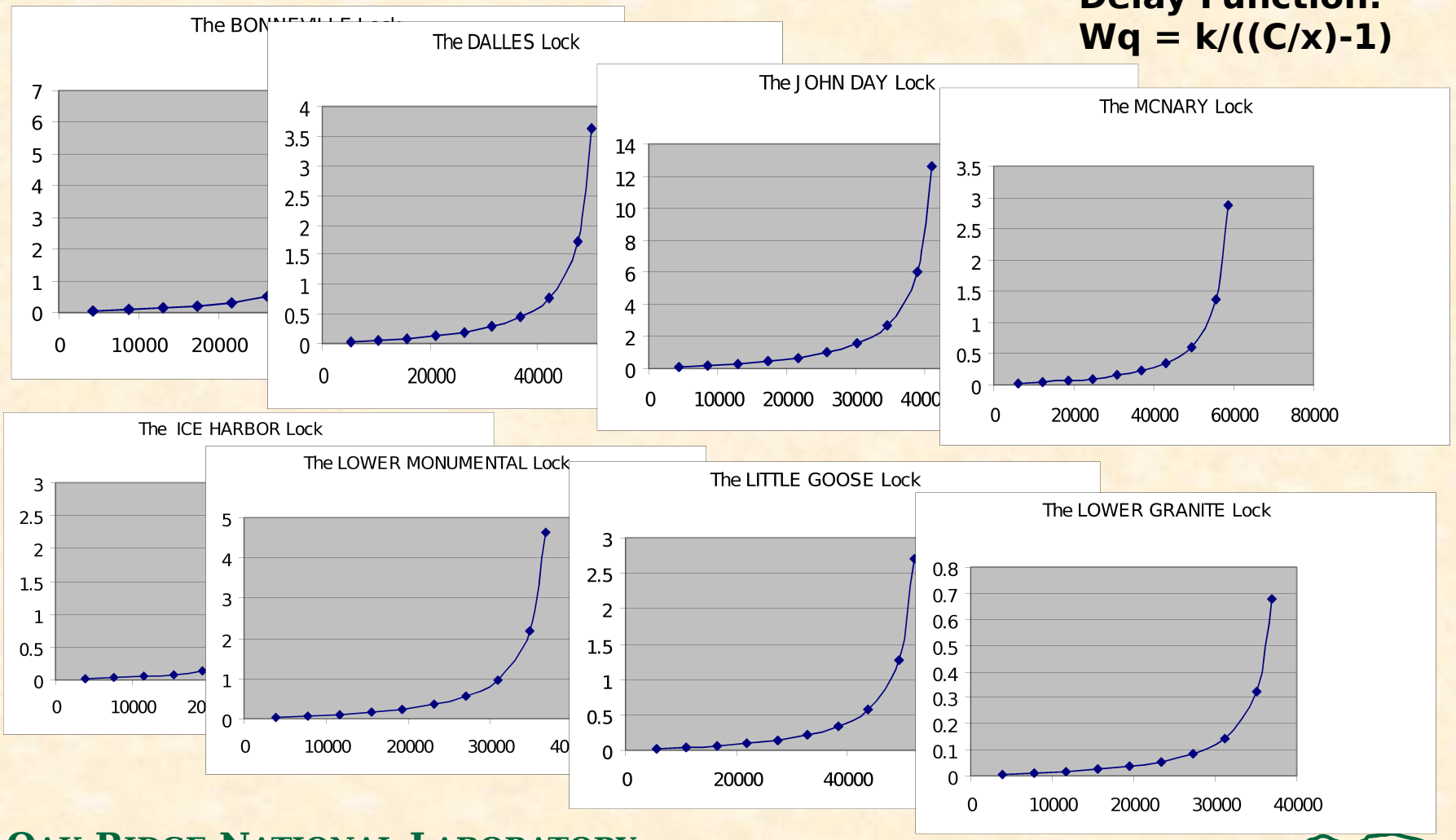
1) USACE supplied average tow space mean speeds by river section
2) Modeling of lock transit plus delay times using USACE's LPMS data

VALIDATION: fitted to LPMS monthly lock performance data

MULTICOMMODITY WATERWAY ASSIGNMENT SUB-MODEL

The Key is Effective Modeling of Lock Link Congestion Funct

Default Lock Transit Delay Function:
Wq = k/((C/x)-1)



Currently Using Hyperbolic Lock Delay Functions (in lieu of ORNIM or similar TIER 3 model inputs)

Lock link transit time = processing time plus delay

Average delay per tow = f (kilotons through lock per time period)

Delays are modeled as: $Wq = k/((C/x)-1)$

where:

Wq = the average queue waiting time per tow at the lock, in minutes

C = lock capacity, estimated as NT* (average tons/tow)

for NT = maximum number of tows processed per year at the lock, given in turn by:

NT = TM/PT

for TM = total number of minutes the lock is open in the year

and PT = the average processing time per tow over the course of the year

and k = the average delay per tow, in minutes, at 50% lock throughput capacity

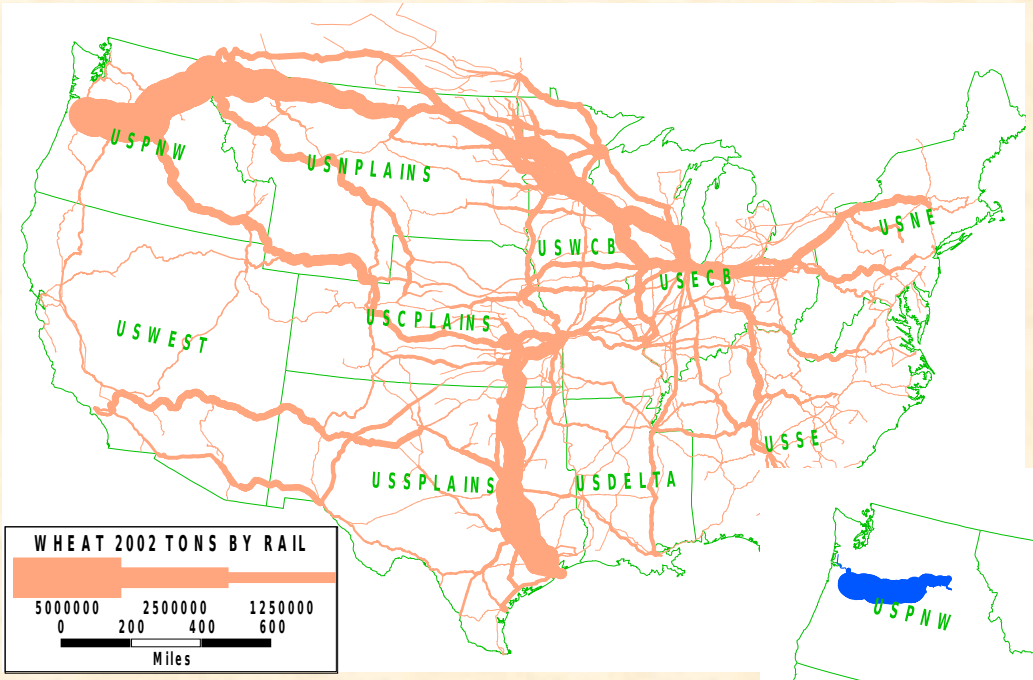
x = the traffic volume at the lock, in kilotons per year.

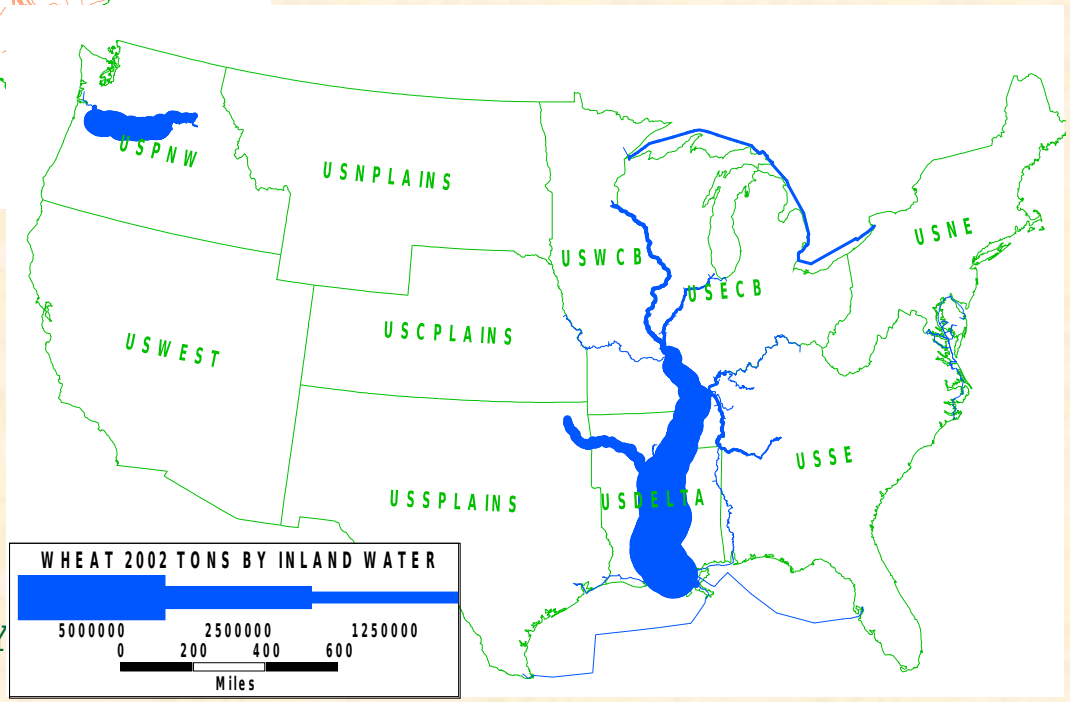
MS Excel Spreadsheet Model based on 1999 monthly LPMS data

MULTI-COMMODITY ASSIGNMENT: MODEL OUTPUTS

GIS Mapping of Annual Flow Volumes

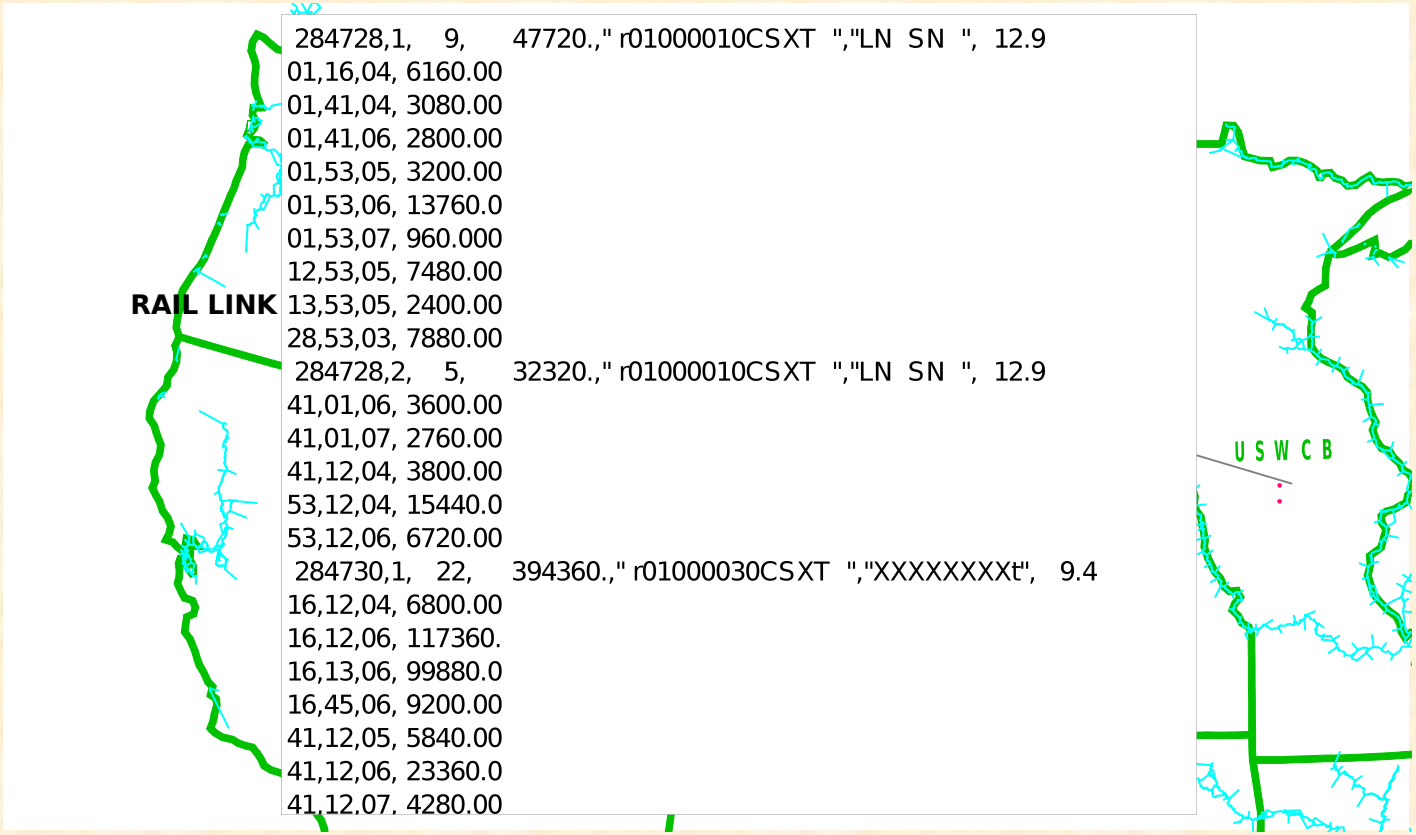
Annual Wheat Shipments by Rail & Inland water (2002 tons)





MULTI-COMMODITY ASSIGNMENT: MODEL OUTPUTS

Estimated O-D-C Flows Through an Individual Rail Link



A BENEFIT OF THE CURRENT APPROACH is that it allows extensive "back-tracing" of specific O-D-C flows to specific network links

RRM SCENARIO ANALYSIS:

Connecting National Rail and Water Freight Movement to Regional Flows

Multi-Commodity, Congestion-Sensitive National Rail Routing Algorithm

Regional Truck-Rail-Waterway Mode and Route Choice Model (RRM)

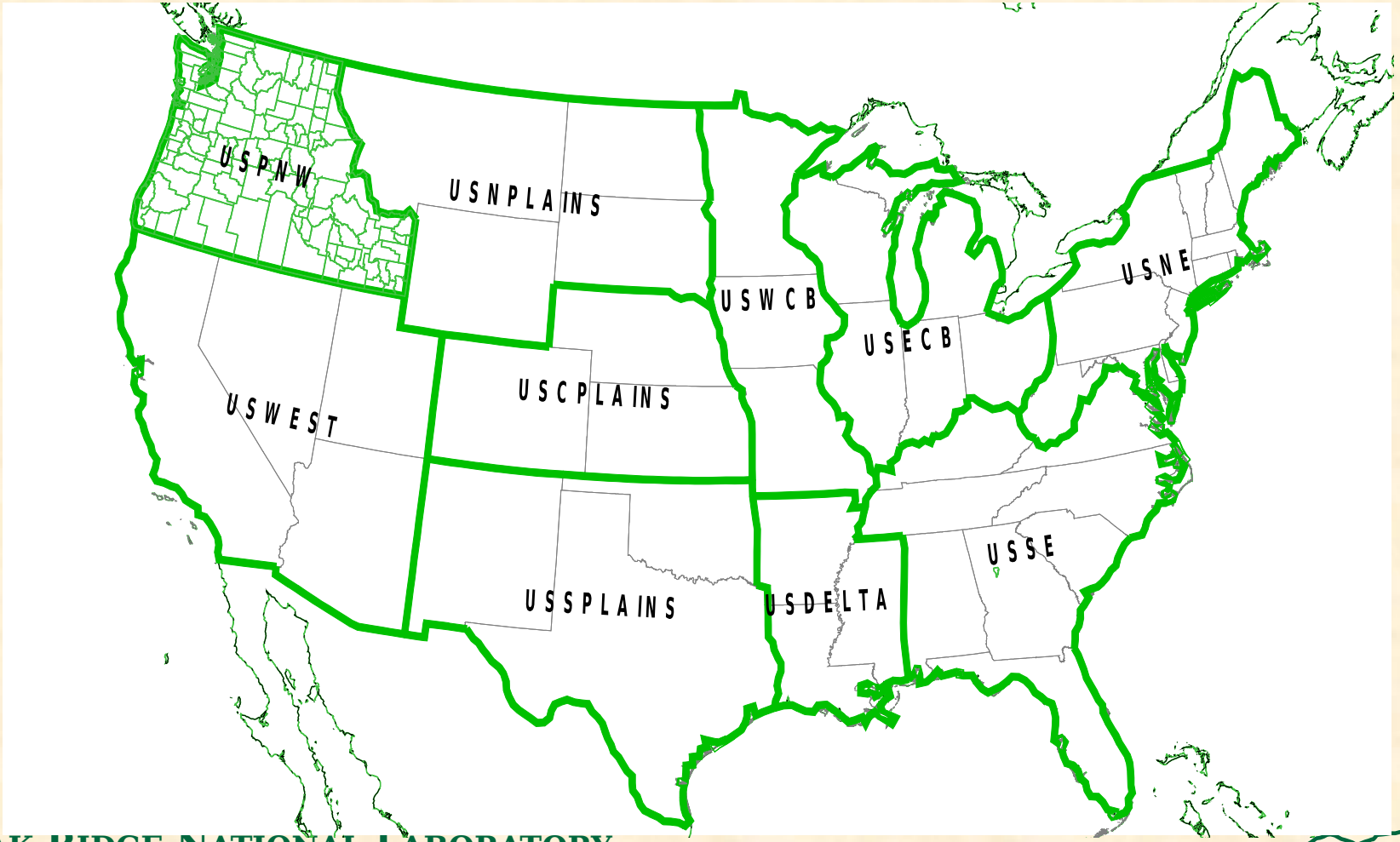
= Calibration

Scenario 1 **Base Case Scenario (2002)**

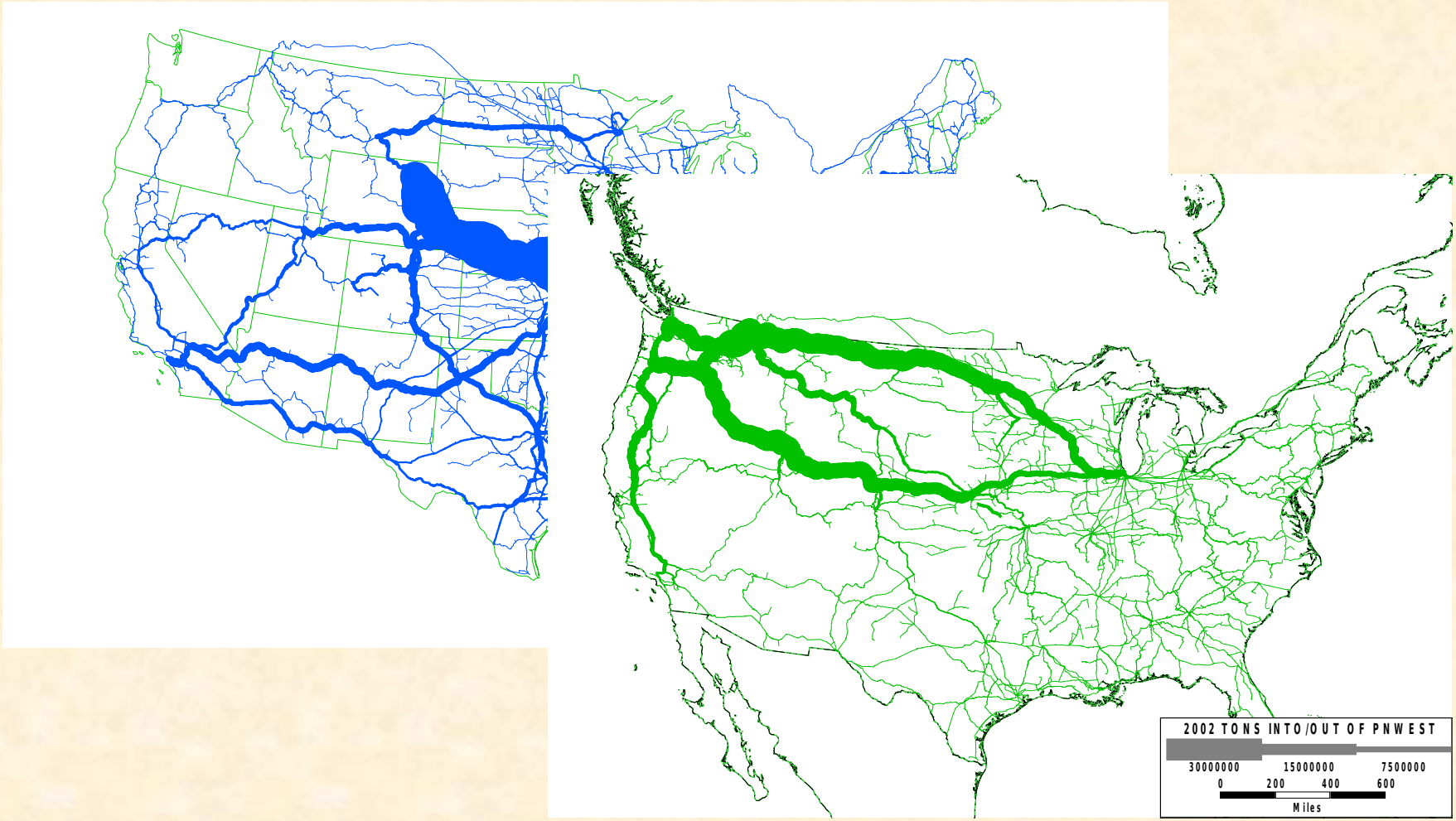
Scenario 2 **Network Capacity Reduction**

Scenario 3 **Increased Production/Consumption**

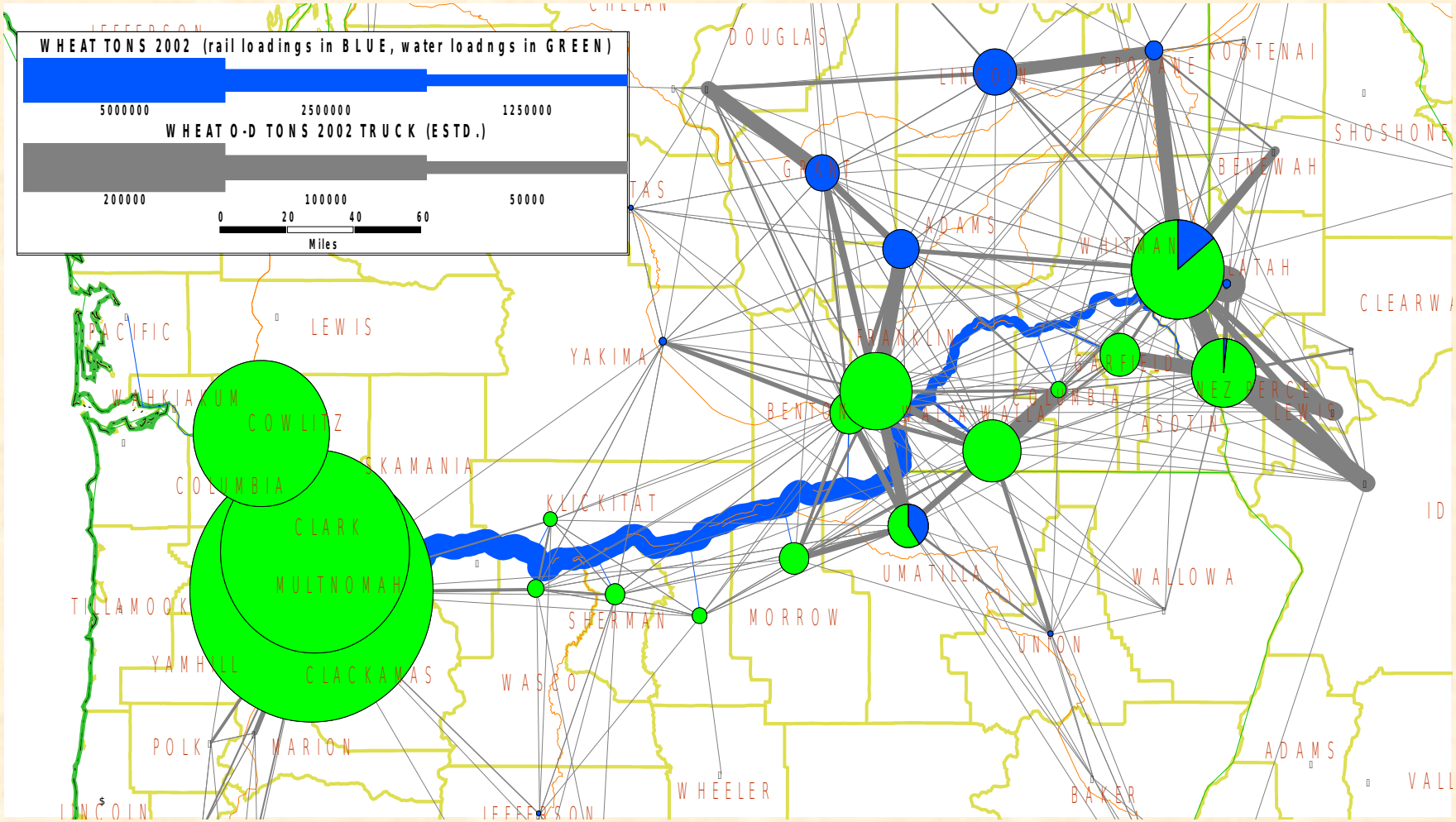
RRM: REGIONAL ANALYSIS
NETS Tier 1 Grain Producing Macro-Regions with Pacific Northwest Tier 2 County Disaggregation



Identifying Commodity Markets that Affect Within-Waterway-Region

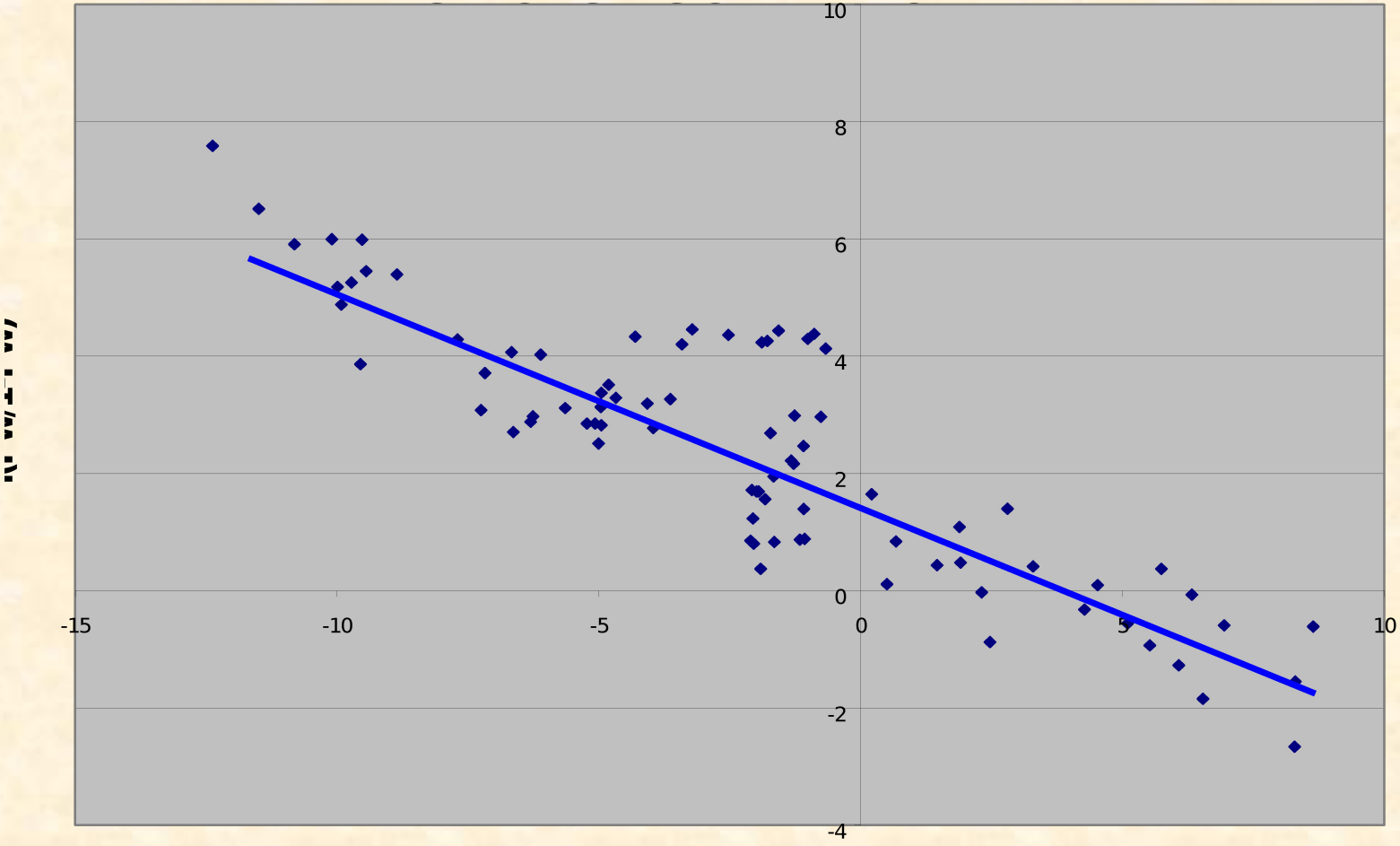


LINKING TRUCK FLOWS TO RAIL/WATER MOVEMENTS:
Estimated Wheat Movements (Annual Tons) in the Pacific Nor



RRM Mode Choice Sub-Model

Pacific Northwest Wheat Flows, 2002



Pw= 1/1+exp [1.569-0.359*(Cw-Cr)]

Pw = 1/1+exp[-0.49158*(Cw-Cr)]

SCENARIOS ANALYSIS

Results from Initial Tests (Very Preliminary)

Commodity : Annual Wheat Flows
Region: Pacific Northwest (ID,OR,WA)
River System : Columbia –Snake

v1 = Base year (2002) calibration

v2 = Adjusted Base year calibration incorporating more realistic railroad interlining costs

Scenario 2 = loss of rail capacity in Columbia Gorge (BNSF)

Scenario 3 = 20% increase in national wheat flows

A) Rail Travel Time Effects (Increases) are noticeable :

B) Waterway times increase only marginally (< 5%)

C) BUT: all model estimated Mode Shifts are small (too small???)
: circa 1% regional shift to water

Example Rail Time Effects:

		tons	ton-hours/1000	% increase	ton-miles/1000	% increase	av.speed (mph)
Base Case v1	ALL Commodities	95.703.094	6.062.159	0.0	138.482.319	0.0	22.8
	WHEAT	7.505.113	361.274	0.0	8.698.121	0.0	24.1
Scenario 2 v1	ALL Commodities	95.703.094	7.141.090	17.8	143.353.749	3.5	20.1
	WHEAT	7.505.113	461.358	27.7	8.921.867	2.6	19.3
Base Case v2	ALL Commodities	95.703.094	7.174.717	0.0	138.865.825	0.0	19.4
	WHEAT	7.505.113	451.288	0.0	8.544.783	0.0	18.9
Scenario 2 v2	ALL Commodities	95.703.094	7.288.365	1.6	140.314.119	1.0	19.3
	WHEAT	7.505.113	475.419	5.3	8.973.901	5.0	18.9
Base Case v1	ALL Commodities	95.703.094	6.062.159	0.0	138.482.319	0.0	22.8
	WHEAT	7.505.113	363.373	0.0	8.733.365	0.0	22.5
Scenario 3 v1	ALL Commodities	97.204.117	6.590.173	8.7	140.654.298	1.6	19.9
	WHEAT	9.006.136	488.172	34.3	10.478.732	20.0	19.2